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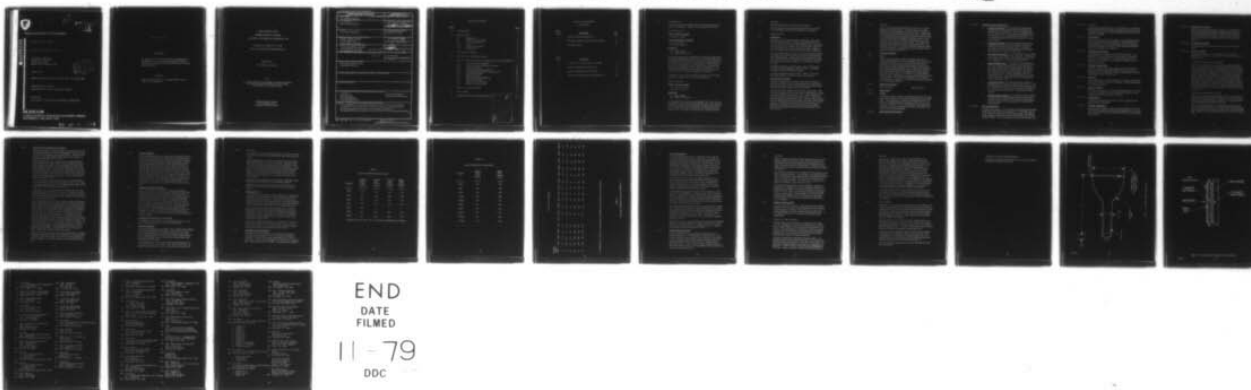
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HIGH CONTRAST CRT.(U)  
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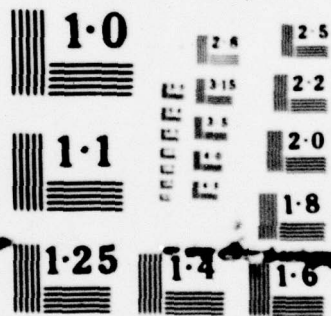
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NATIONAL BUREAU OF STANDARDS  
MICROCOPY RESOLUTION TEST CHART



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## Research and Development Technical Report

DELET - TR - 77 - 2639 - 5 ✓

HIGH CONTRAST CRT

Dr. Glenn A. Holmquist  
Watkins-Johnson Company ✓  
440 Mt. Hermon Rd.  
Scotts Valley, California 95066

August, 1979

Fifth Interim Report for Period 1 October 1978 - 28 February 1979

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Prepared for:

ELECTRONICS TECHNOLOGY AND DEVICES LABORATORY

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**HIGH CONTRAST CRT  
INTERIM TECHNICAL REPORT  
1 OCTOBER 1978 THROUGH 28 FEBRUARY 1979**

**Contract No. DAAB-07-77-C-2639  
File No. WJ-672705A 1L162705AH94 D1 08**

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21. ABSTRACT (Continue on reverse side if necessary and identify by block number) <b>Sixteen faceplates were completed and characteristic optical data was recorded. The difficulties in production result from the properties of the faceplate glass limiting the maximum temperature of the La<sub>2</sub>O<sub>3</sub>S heat treatment. The optimum fabrication techniques, with this limitation, produced quality faceplates.</b>		

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## CONFERENCES

13 September 1978 at Lockheed Palo Alto Research Laboratory in Palo Alto, California. Progress was reviewed and discussed.

## Personnel Present:

Watkins-Johnson Company

Norman H. Lehrer

Lockheed Research Laboratory

Dr. Grant Maple

Dr. Robert Buchanan

ERADCOM

Dr. Elliott Schlam

Mr. Phillip Krzyzkowski

The reproducibility of the cathodoluminescent thin film fabrication technique needed further improvement. This had been recognized by Lockheed personnel and they were directing a major portion of their effort to resolve this. Reproducibility is indicated by measurements of the cathodoluminescent efficiency, and the diffuse and specular reflectivity of the complete composite films. The equipment and techniques for these optical measurements were actively discussed. Improved techniques were planned.

14 September 1978 at Watkins-Johnson Company in Scotts Valley, California. Progress was reviewed and discussed.

## Personnel Present:

Watkins-Johnson Company

Mr. Norman H. Lehrer

Mr. John L. Turner

ERADCOM

Dr. Elliott Schlam

Mr. Phillip Krzyzkowski

Four faceplates were received and fabricated into CRTs. One of four achieved successful operation (faceplate #19). Data measured at 10kV (red) showed it to have improved brightness over the previous two tubes completed. Specifically, the improvement was a factor of four. This tube utilized an Einzel electron gun rather

1.0

Continued

than the bipotential gun used in the first two tubes.

The Einzel gun tube has electrical requirements most similar to the monochrome tube that was proposed to be replaced.

2.0

## INTRODUCTION

2.1

### Background

Development of the high contrast two-color tube, which is the objective of this program, encompasses the fabrication of the screens and their assembly into the completed tube. The screens are being made by the Lockheed Palo Alto Research Laboratory under subcontract from Watkins-Johnson Company. Watkins-Johnson will assemble the completed screens into finished tubes.

The major thrust of this program is the screen fabrication effort, particularly the application of these screens to a thin film phosphor cathode-ray tube. Effort on the screens was late in starting because of the delay in awarding the subcontract to the Lockheed Palo Alto Research Laboratory. This occurred in September, 1978.

Faceplate fabrication proceeded in this interim culminating in the delivery of 16 faceplates by March 1, 1979. The bulk of this report concerns the fabrication effort.

In December Watkins-Johnson hired Dr. Glenn A. Holmquist. His responsibilities will include work on this program.

2.2

### Statement of the Problem

The basic objective of this program is the ability to display information generated by various electronic systems with suitable high resolution in two colors with its legibility maintained under ambient illumination ranging from  $10^4$  to  $10^{-3}$  fc.

Existing color tubes cannot satisfy the above requirement. Such tubes which employ aperture masks are severely limited in brightness and resolution by the aperture mask. Their brightness is limited because the aperture mask transmission is only 15-20%, therefore wasting 80-85% of the current. The wide spacing between holes degrades the resolution below that required in most military systems. Furthermore, the color purity of such tubes is influenced by their position with respect to the earth's magnetic field and it is therefore impractical to incorporate them in airborne systems.



2.2

Continued

The use of color penetration phosphors overcomes some of the problems of mask type tubes. The color purity is no longer affected by the tube orientation and the resolution is higher than that which can be achieved with a mask type tube. Conventional color penetration tubes which employ powdered phosphors cannot be used for daylight (high brightness) viewing because of their high reflectivity and low brightness particularly in red, which produces a washed-out low contrast display. The reflectivity of the phosphor is high because of its particulate nature. The brightness of the red is low because most of the light generated by the red phosphor is scattered by the green phosphor before it reaches the faceplate of the CRT.

2.3

Technical Guidelines

2.3.1

Scope

These technical guidelines outline a program leading to the design and fabrication of a very high contrast CRT. The screen phosphors of this CRT are to be of the transparent film type and backed by a black light absorption coating. Therefore, a prime objective of this program is the incorporation of a phosphor-screen technology that will result in transparent film phosphors deposited on a substrate-faceplate which is an integral part of the CRT envelope. It is furthermore intended that the phosphor screen incorporate a two layer, penetration type multi-color structure. This phosphored faceplate is to be attached to available tube envelopes in a manner consistent with economical CRT manufacturing methods.

2.3.2

Applicable Documents

MIL-E-1 Manual

MIL-STD-1311A

2.3.3

Requirements

2.3.3.1

General

This program shall be directed toward the development of a high contrast CRT based on the use of high efficiency transparent phosphors. This capability is intended to accomplish this by an extension of available phosphor techniques to CRT sizes now used in military equipment. Areas of investigation and performance will include, but not necessarily be limited to, the features outlined in the following paragraphs.

2.3.3.2

Detailed Program Objectives

#### 2.3.3.2.1

#### Phosphor Screen Characteristics

- 1) Luminescent Material - The luminescent material shall be one that has a demonstrated high cathodoluminescent efficiency in transparent form. Since it is intended that bi-layer films be used, the demonstrated efficiency should be with various colors, particularly red and green. It is not intended that phosphor development per se, be part of this program.
- 2) Phosphor Persistence - The transparent phosphors used in the CRT screen should have persistence in the range of JEDEC designations "medium short" to "medium". Trade-offs of persistence with other phosphor properties and characteristics should be determined.
- 3) Physical Characteristics - It is intended that a bi-layer type of phosphor screen shall be used in the CRT. In that event, each phosphor layer shall be transparent and may or may not be separated by a transparent dielectric layer.
- 4) Light Absorbing Layer - A requirement of this program is that the phosphor screens be backed, on the electron gun side, with a uniform light absorbing coating that can be effectively penetrated by the electron beam. Specular reflection from this coating, on the phosphor side, should be no greater than 1%. Diffuse reflectance shall be no greater than 0.25%. This coating shall not cause any substantial reduction in electron-current or electron-energy into the phosphor screen.
- 5) Phosphor Electrode - The phosphor electrode shall be a thin aluminum film, behind the black coating of 2.3.3.2.1-4, and electrically insulated from all other tube electrodes by means sufficient to withstand the operating levels within the tube without electrical breakdown or appreciable leakage current.
- 6) Phosphor Screen Substrate - The phosphor screen substrate shall be capable of withstanding all necessary fabrication techniques of the transparent film screen without change of shape or curvature that would degrade the end result of a completed CRT.

#### 2.3.3.2.2

#### CRT Characteristics

The goal of this program is a CRT that is physically and electrically replaceable with a currently existing CRT. To this effect, the envelope, deflection angle and means, focusing means, and biasing should duplicate a Dumont KC3055 (formerly KC2626) CRT used in the AN/A PR-39. It is accepted that an improved electron gun may

2.3.3.2.2 Continued

be used with this phosphor screen. To this effect, it is desirable that the final CRT be electrically interchangeable with the KC3055, as closely as possible, so that power supplies driving the KC3055 need not be replaced.

2.3.3.2.3 CRT Contrast

It is necessary that the CRT be legible in direct sunlight under its normal mode of operation, without the use of added contrast enhancement devices. Specific quantitative criteria to satisfy this requirement should be developed so that optical instrumentation tests may be used for its verification.

2.3.3.2.4 Faceplate Characteristics

The faceplate size should be directed to the above CRT. The faceplates shall be bonded to the tube envelope by conventional means or use of graded seals. Glass-to-metal seals are undesirable. This program is not intended to support special envelope development.

2.3.3.2.5 Phosphor Voltage Range

The CRT should operate within conventional limits of anode potential. In no case should this potential exceed 20kV. In the penetration screen configuration, anode potential shifts to achieve color changes should be minimized.

2.3.3.2.6 Resolution

A line width, taken at the half amplitude point of the spot distribution, of 0.012 inches or better is desirable. The line width should not exceed 0.016 inches.

2.3.3.2.7 Display Luminance

The CRT is to operate under ambient illumination from  $10^4$  to  $10^{-3}$  fc. The CRT luminance is to be uniformly adjustable to provide satisfactory legibility under these conditions.

2.3.3.2.8 Writing Speed

A minimum writing rate of 50,000 in/sec for a single trace for all color fields is desirable.

2.3.3.2.9 Phosphor Maintenance

The transparent phosphors shall have high maintenance under normal modes of operation consistent with paragraph 2.3.3.2.3, and burn sensitivity test shall be conducted on the screens incorporated into the CRT.



#### 2.3.3.2.10 Reliability Consideration

Since the CRTs developed under this program are intended for tactical and airborne applications, adequate consideration must be given throughout the development program to the reliability of this tube for such environments. As an objective, the CRT should be able to pass the physical tests for CRTs specified in MIL-E-1.

#### 2.3.3.2.11 Environmental Testing

Environmental testing of the CRTs will not be part of this program.

#### 2.3.3.2.12 Program Emphasis

The program emphasizes the investigative areas outlined in paragraphs 2.3.3.2.1-1), 2.3.3.2.1-4), 2.3.3.2.2), 2.3.3.2.3), and 2.3.3.2.7).

### 3.0 TECHNICAL APPROACH (TUBE DESIGN)

Figure 1 is a schematic of the proposed high contrast multicolor CRT. The physical dimensions are identical with that of the existing CRT (Dumont KC3055). The high contrast tube will employ a Laminarflo Gun. This gun offers advantages over the crossover gun and is described in Reference 1. The phosphor screen incorporates a black backed multilayer bicolor transparent phosphor film deposited on a substrate which is bonded to the CRT funnel. The details of this screen are described further in this report. In operation, the color of the display can be controlled by selection of the beam potential. At about 10kV, the display will be red, at 15-20kV the display will be green. With the exception of the focus and anode potentials, the operating voltage will be the same as the existing CRT.

### 4.0 THE THIN FILM PHOSPHOR SCREEN

Figure 2 is a schematic representation of the two-color high contrast film to be employed in this program. As shown in the illustration, the two-color phosphor is supported on a transparent substrate which forms the faceplate of the CRT.

The green-luminescent film is immediately adjacent to the substrate. The red-luminescent film resides on top of the green one. The opaque layer is deposited on the other face of the red phosphor film. Finally, a thin conducting aluminum layer covers the opaque layer.

4.0

Continued

In operation, the red phosphor layer absorbs most or all of the electron beam energy at potentials below 10kV. At high potentials, for example, at 20kV, most of the electron beam is absorbed in the green phosphor. At intermediate potentials, some electrons are absorbed by both layers, depending upon the exact value of the potential. (A mathematical description of the optimum film thickness is given in the proposal.) Therefore, at low beam energies, only the red phosphor is excited and the display appears red. At high beam energies, the green-luminescent material is more excited and the display appears green. Various mixtures of the two colors are obtained at intermediate values of the potential. Note that since the luminous efficiency of the red is much lower than that of the green, it is important that the red be placed closest to the electron gun, to prevent color contamination of the red by the green. If the green film were closest to the gun it would not be possible to excite the red without getting some color contamination from the green phosphor.

The operation of this screen in high ambient lighting conditions was discussed in our proposal, P-4583.

5.0

#### THIN FILM PHOSPHOR SCREEN FABRICATION AND MEASUREMENT

During this interim Lockheed Palo Alto Research Laboratory fabricated and delivered 15 faceplates to Watkins-Johnson and one to ERADCOM (#26). The correct thin film deposition technique had been previously determined leaving only the last details to be correctly determined. One detail developed into a problem: the mechanical strength of the glass at elevated temperature.

5.1

##### 1720 Glass Structural Integrity

The main problem was maintaining the structural integrity of the 1720 glass faceplate during necessary post heat treatments. Surface distortion and bulk warpage were observed. The cathodoluminescent properties of the deposited phosphor thin film are improved to an acceptable quality by a heat treatment in a  $H_2+SO_2$  atmosphere. Maximum improvement occurs with heat treatment at 1050°C. The 1720 glass faceplate can not withstand this temperature without deforming. The heat treatment temperature must be less than 915°C with the corresponding diminished cathodoluminescent improvement.

The temperature - mechanical strength properties of 1720 glass are revealed in Table 1. At 667°C, the glass just begins to deform under load. Increasing the temperature to 915°C, the glass deforms under its own weight. Between these temperatures the glass may deform if subjected to stress (load).

1720 Glass Temperature (°C)	Viscosity (Poise)	
1200	$10^4$	Working Point
915	$10^{7.6}$	Softening Point
712	$10^{13.4}$	Annealing Point
667	$10^{14}$	Strain Point
		Plastic liquid
		Deforms under its own weight
		Strain free in 15 minutes
		No longer rigid under load

TABLE 1    Viscosity - Temperature Data    1720 Glass



Surface Distortion Problems and Solution

The faceplate surface distortion problem was encountered during the  $H_2+SO_2$  treatment at elevated temperature which is necessary to improve the brightness of the phosphor films. Distortion continued to be a problem although the treatment temperature was lowered in steps from 870°C to 825°C.

The surface distortion was in the form of a somewhat complex pattern in that the uncoated surface of the 1720 glass had frosty areas together with clear areas which appeared to have melted. These clear areas looked somewhat like spokes of a wheel, and were generally concave. In all cases, the distortion was confined to regions of the front (uncoated) surface opposite the film-coated area of the back surface (Figure 3). There was no surface distortion in the border region opposite the 1/4 inch wide uncoated border area on the film side.

It was found that no surface distortion of an uncoated 1720 glass disc occurred at 844°C for one hour in argon, while a disc coated with  $La_2O_2S$  phosphor films showed surface distortion after treatment at the same temperature in the  $H_2+SO_2$ .

A further test was made by treating an uncoated 1720 disc in the  $H_2+SO_2$  atmosphere at 870°C for one hour. No surface distortion of the disc occurred, thus ruling out any reaction between the carbon support plate and the glass disc that might have been promoted by the active gaseous ambient.

It is concluded that the very unusual surface distortion observed on treating coated discs is the result of stress arising from the difference in thermal expansion coefficients between the phosphor film and the glass. The linear coefficients for  $La_2O_2S$  and 1720 glass are  $6 \times 10^{-6}$  per °C (300-500°K) and  $4.2 \times 10^{-6}$  per °C (273-573°K), respectively. A comparable difference probably exists at 870°C (1143°K), although no literature values are available for either material at this higher temperature. At the treatment temperature, the mismatch of expansion coefficients between film and glass produces a tensile stress upon the coated surface of the glass. As the temperature exceeds the strain point, the stress is relieved by viscous flow of the glass. On subsequent cooling from 870°C to 667°C the coated surface would be constrained to contract faster than the uncoated surface. Cooling below 667°C the then rigid glass would be placed under compressive stress.

The surface distortion mechanism was not more definitively defined. The final solution appeared to be the selection of a better faceplate material. The interim solution was to remove the distorted surface by polishing. The interim solution was successful and expedient.

### 5.1.2

#### Warped Faceplate

The faceplates would warp to varying degrees during heat treatment. The thermal expansion coefficient mismatch discussed in the previous paragraph results in the  $\text{La}_2\text{O}_3\text{S}$  coating applying a stress to the glass substrate at elevated temperature. During heat treatment the glass is under stress during heating until temperatures above  $667^\circ\text{C}$  when the glass flows to relieve this stress. Holding at the maximum temperature ( $870^\circ\text{C}$ ) for one hour, the glass has time to equilibrate to a strain free condition. When cooling to  $667^\circ\text{C}$ , stress is relieved by viscous flow. However, the  $\text{La}_2\text{O}_3\text{S}$  coated surface is constrained to contract more than the other side and this strained (Figure 3) or warped condition is "frozen in" as the faceplate cools below  $667^\circ\text{C}$  to room temperature. This strained or warped condition (this is not surface distortion) does not manifest itself as a problem at this time.

### 5.1.3

#### Slumping During Heat Treatment

It was reported (WJ-78-4161MR17) that the glass faceplate slumped to conform to the supporting substrate during the  $870^\circ\text{C}$  heat treatment. Moreover the problem was solved by polishing the substrate flat. The verb slump is not entirely accurate. Slumping is glass deforming under its own weight (softening point of 1720 glass is  $915^\circ\text{C}$ ). Slumping will not occur unless the temperature is increased  $45^\circ$  to  $915^\circ\text{C}$ . However, the concave substrate would accommodate the concave warpage just discussed (5.1.2) as the faceplate was placed on the substrate coated side up. The differential thermal expansion plus the unsupported weight of the faceplate combined to make the glass "slump". It was observed the flat substrate reduced this deformation appreciably.

### 5.2

#### Reflectance and Brightness Measurements

The reflectance and brightness measurement techniques were defined in the second interim report (ECOM-77-2639-2).

### 5.2.1

#### Specular Reflectance

The specular reflectance for faceplates XXII - XXVIII were initially measured on the distorted faceplates at selected positions that were visually frost-free. In general, these areas were concave, and it is probable that some of the incident light escaped detection by the photometer by reason of reflection at an angle other than the apparent incident angle.

The faceplates were measured again after optical polishing to remove the distortion. The average of the measurements was 0.3% higher than that for the previous measurements (Faceplate XXVI

### 5.2.1

#### Continued

was sent to Mr. Krzyzkowski for polishing on the Mazur machine at ECOM and was thus not available for the after-polish measurements).

Specular reflections were again measured for this group of faceplates eight days later, at the time the diffuse reflectance measurements were made. The values were lower than the second measurements, and higher than the initial measurements. There was also a somewhat smaller spread of the individual faceplate values. This may be the result of improved operator skill or perhaps due to aging of the polished surfaces; it is well known that a reduction of reflectance is associated with aging of polished surfaces.

The results of the reflectance measurements for faceplates XXII-XXVIII are summarized in the accompanying Table 2.

Reflectance measurements for faceplates XXIX-XXXVII were made by Lockheed only after polishing and are summarized in Table 3.

### 5.2.2

#### Diffuse Reflectance

Two methods were used for the diffuse reflectance measurements. In the first method the sample was rotated 16 degrees from the specular measurement position. This produced an angle of incidence of  $10^\circ$  and a measuring angle for the scattered or diffusely reflected light of  $16^\circ$ . The signal measured in the diffuse position was referenced to the signal obtained in the specular position.

In the second method, the physical arrangement was identical, but the sensitivity of the Pritchard Spot Brightness meter was increased by a factor of 10 and the measured signal referenced to that obtained from a diffuse source (513 Glo Paint on Dow 17 substrate) for which a reflectance of 0.89 had been previously determined for visible light.

For the first method, all samples gave a value of  $0 \pm 0.008$ ; for the second method, all samples gave a value of  $0.007 \pm 0.001$ . In the second method, it is suspected that the measured signal is largely due to stray light in the measurement room.

### 5.2.3

#### Cathodoluminescent Brightness

Cathodoluminescent brightness of the faceplate was measured at a beam current of  $5\mu\text{A}$  at a series of electron accelerating potentials, using the demountable cathodoluminescence measuring system. The results, normalized with respect to an  $\text{La}_2\text{O}_3\text{:Tb}$  film on sapphire processed at  $1050^\circ\text{C}$ , are summarized in Table 4.



TABLE 2  
Results of Reflectance Measurements

Faceplate No.	Specular Before Polish, 1-12-79	Specular After Polish, 2-12-79	Specular After Polish, 2-20-79	Diffuse After Polish, 2-10-79
XXII	.054	.051	.050	< .010
XXIII	.056	.058	.055	< .010
XXIV	.047	.054	.053	< .010
XXV	.052	.058	.055	< .010
XXVI	.046	--	--	--
XXVII	.053	.057	.055	< .010
XXVIII	.054	.053	.053	< .010

Faceplate XXVI was sent to Mr. Krzyzkowski at ERADCOM for polishing.

TABLE 3

## Results of Reflectance Measurements

Faceplate No.	Specular After Polish, 2-21-79	Diffuse After Polish, 2-21-79
XXIX	.061	.007
XXX	.059	.006
XXXI	.055	.006
XXXII	.064	.007
XXXIII	.060	.007
XXXIV	.055	.007
XXXV	.058	.009
XXXVI	.060	.009
XXXVII	.057	.006
Average	.059	.007

# FACEPLATE NUMBERS

Electron Energy KeV	XXII	XXIII	XXIV	XXV	XXVI	XXVII	XXVIII	XXIX	XXX	XXXI	XXXII	XXXIII	XXXIV	XXXV	XXXVI	XXXVII
6	0.8	0.4	0.7	0.9	*	0.6	0.7	1.0	0.2	0.2	0.7	0.3	0.7	1.3	0.9	0.4
8	11.0	13	10	16.2	-	19.6	15.5	17.5	6.3	5.2	11.7	8.0	11.8	23.0	16	10.6
10	55	51	52	61	-	76	58	60	32	32	43	29	48	75	54	39
12	130	114	126	136	-	170	131	133	80	94	97	91	106	163	126	95
14	243	224	235	239	-	318	240	249	178	186	192	175	205	286	240	177
15	310	276	293	291	-	388	294	305	224	233	227	240	273	333	308	229

\* Not measured. Sent to Mr. Krzyzkowski at ERADCOM for polishing on Mazor machine.

TABLE 4  
Measured Cathodoluminescence Brightness, fL



### NR Film Degradation

The non-reflecting (NR) film may suffer from heat treatments in subsequent CRT fabrication. The NR film is a graded composition of vanadium and oxygen and is deposited after the phosphor thin film ( $\text{La}_2\text{O}_2\text{S}$ ) is heat treated. In processing, the frit sealing cycle might promote solid state diffusion of vanadium and/or oxygen in the film. This diffusion would become evident as an increase in reflectivity and transmission. At elevated temperatures the possibility of a reaction exists between the NR and  $\text{La}_2\text{O}_2\text{S}$  films. This would result in a decrease in the cathodoluminescent brightness of the  $\text{La}_2\text{O}_2\text{S}$  film.

A study was made to determine the effect of exposure of the phosphor film - NR film combination to elevated temperature for a period of time in an inert atmosphere. Conditions were chosen to simulate those of sealing the cathode ray tube faceplates to the tube envelope during assembly which is typically  $640^\circ\text{C}$  in a nitrogen atmosphere for one hour.

An 8000Å film of  $\text{La}_2\text{O}_2\text{S}:\text{Tb}$  phosphor was deposited on a 3 inch diameter disc of 1720 glass identical to those used for the faceplates. A non-reflective vanadium-based film was next deposited over the phosphor. One half of the disc was masked and 800Å of aluminum deposited on the unmasked NR film area. Specular reflectivities were measured for the aluminum-coated and uncoated areas from the faceplate viewing side.

The disc was then divided into a number of pieces using a diamond saw. After thorough rinsing to remove sawing debris, the pieces were dried. Pairs of aluminum-coated and uncoated pieces were subjected to temperatures of  $652^\circ$ ,  $627^\circ$ , and  $604^\circ\text{C}$  in an argon atmosphere of a tube furnace for 1 hour. Argon 99.99% was selected as the ambient atmosphere to insure complete inertness toward the NR film.

Nitrogen, however, is presently used as the actual sealing ambient and there is some possibility of an effect on the NR film by reaction of vanadium with nitrogen. The literature (Ref. 1) suggests such reaction would be minimal below  $700^\circ\text{C}$ .

#### 5.3.1

### Reflectivity Measurements

Specular reflectivities were subsequently measured on the individual test pieces. The reflectivities of all test pieces is seen to have increased. The average increase was 20%. The increase for the aluminum-coated samples was about half that of the non-aluminum-coated samples at  $605^\circ$  and  $627^\circ\text{C}$ , but practically identical at  $652^\circ\text{C}$ . A more extensive study would be required to draw valid conclusions as to any real difference between aluminum-coated and uncoated faceplates.

### 5.3.1

#### Continued

Before treatment the samples without aluminum had the normal metallic vanadium appearance of their back sides and had low light transmission as viewed against the laboratory fluorescent lamps from their front side after treatment. All three samples without aluminum lost their metallic appearance and had increased transmission.

The samples with aluminum were opaque due to the aluminum both before and after treatment. The aluminum of the sample treated at 605°C exhibited the usual bright metallic appearance after treatment. The aluminum of those treated at 627°C and 652°C had a yellow tone after treatment. The yellow tone is probably due to diffusion of vanadium metal into the aluminum.

The increase of transparency (and consequently, reflectivity) is probably due to a diffusion of oxygen or vanadium through the graded vanadium NR film, the initial composition of which is believed to be  $V_2O_5$  at the  $La_2O_3$ -NR film interface and metallic vanadium on the outside. An interdiffusion would decrease the oxygen gradient through the film, producing a leveling effect with all portions of the NR film tending toward a uniform lower oxide of vanadium.

### 5.3.2

#### Brightness Measurements

To assess the possible reaction, cathodoluminescent brightness measurements were made on the treated samples and compared with the measured brightness before treatment. There is no significant difference between treated and untreated samples. It was concluded that there is no reaction between the NR and  $La_2O_3$  films.

### 6.0

#### PARALLEL TUBE PROGRAM

Four faceplates were received from Lockheed in early August (#18-21). Faceplate #19 yielded an operational CRT. Measurements revealed a factor of four improvement in brightness (at 10 kV). This improvement was believed to be due to improved cathodoluminescent efficiency of the phosphor film (Lockheed's improvement). An Einzel electron gun was used in this CRT; bipotential guns were used in the comparison.

The history of the three unsuccessful attempts follows. One faceplate was frit sealed satisfactorily; however, the absorbent black layer became transparent. The water, hence oxygen, content of the frit sealing furnace atmosphere was suspected to be excessive. Further oxidation would increase the transmission of the film. Steps were taken to reduce the partial pressure of

6.0

Continued

H<sub>2</sub>O to zero. Before this occurred, a second faceplate (#21) was aluminum coated on 50% of the surface and was then heat treated. The uncoated side suffered an increase in transmission due to the water vapor contaminated furnace atmosphere. This faceplate was fabricated into a CRT and brightness data was measured for either half of the faceplate. The measurements for the coated side were expected to be equal to or less than those for the uncoated side as the fraction of energy used to penetrate the coating would then be unavailable to excite the phosphor. The data was inconclusive as the opposite trend was observed. Essentially the brightness was not affected. The degradation of the absorbing black layer would decrease the contrast and not necessarily the brightness. Qualitative tests were performed at Kaiser Aerospace, Palo Alto, California. The contrast was not significantly different for either half of the faceplate.

The fourth faceplate (#20) was frit sealed to a funnel at too high a temperature. The funnel deformed under the weight of the fixture. To prevent this the furnace was calibrated and the fixture was lightened. Moreover, the faceplate was returned to ERADCOM for salvaging.

7.0

#### CONCLUSIONS

1720 glass is not a perfect faceplate material. The softening point of glass is approached as close as possible during the heat treatment necessary to improve the cathodoluminescent efficiency of the La<sub>2</sub>O<sub>2</sub>S film. The best improvement, without melting the glass, is approximately 70% of that achievable with a much higher melting faceplate material (sapphire). At the beginning of this program glass was favored over sapphire.

Surface distortion on the uncoated surface of the faceplates resulted from heat treatment at 870°C. This problem was resolved by polishing the surface. Warpage of the faceplate also resulted from the heat treatment. It was not excessive and could be accommodated in the frit sealing operation (a grinding step).

The improvement in brightness of the most recent CRT indicates an improvement in Lockheeds sputter deposition and heat treatment technique. An improvement of approximately four was a result of improved process control during sputter deposition and attaining a maximum of 870°C during heat treatment.

Tests to investigate degradation of the absorbing black film have been inconclusive.



8.0

**PROGRAM FOR NEXT INTERIM PERIOD**

**Fabrication of complete CRTs shall occur next interim using the faceplates discribed in this report.**

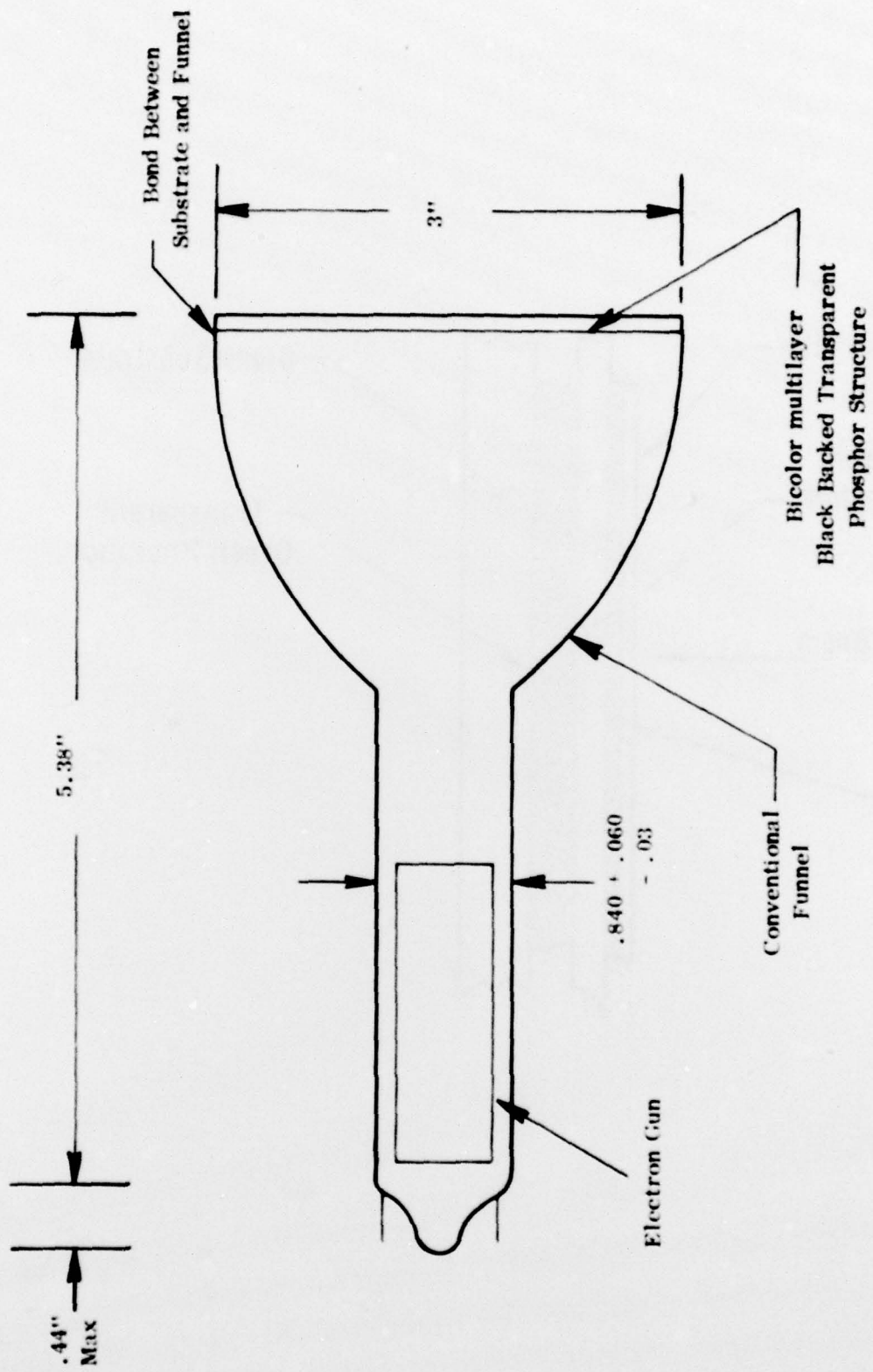


Figure 1. Schematic of High Contrast CRT

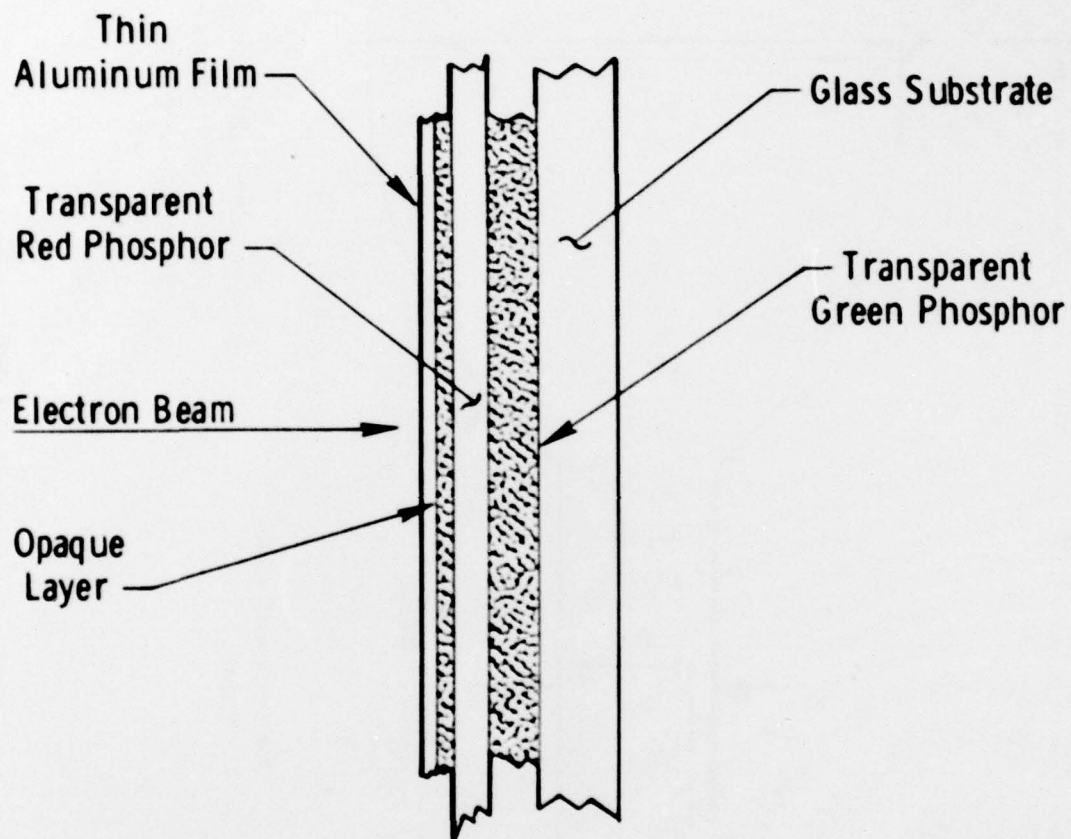
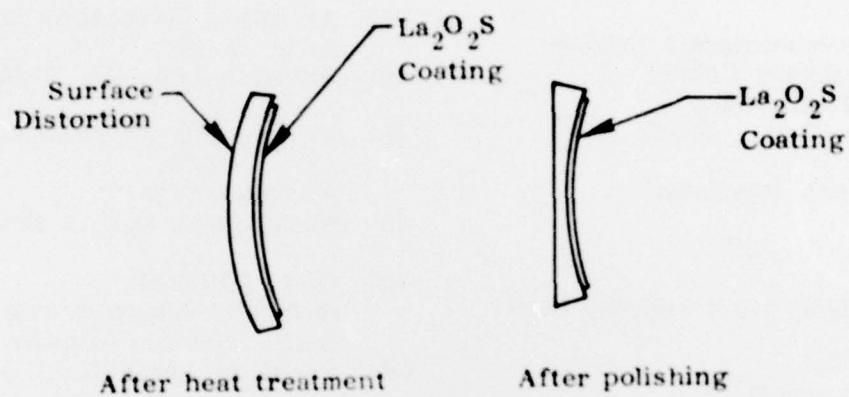


Figure 2. Schematic of High Contrast Two-Color Screen





Cross-section of thickness variation after polishing. Warpage is exaggerated.

Figure 3 - Faceplate Warpage.

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